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Project NY 300 006-5
Project NY 300 006-2
Technical Memorandum M-107

CONSTRUCTION, PERFORMANCE, AND BW
EVALUATION TESTS OF PORT HUENEME
PRESSURIZED BUILDING, JANUARY 1955

15 October 1955

U. S.
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U.S. Naval Civil Engineering Research and Evaluation Laboratory
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**CONSTRUCTION, PERFORMANCE, AND BW
EVALUATION TESTS OF PORT HUENEME
PRESSURIZED BUILDING, JANUARY 1955**

15 October 1955

Ernest N. Hellberg

SUMMARY

Project NY 300 006-5, "Effects of Building Shapes," was initiated to determine whether changing the airflow pattern around a building by altering its shape will affect the penetration of BW aerosol agents and Project NY 300 006-2, "Portable Air Locks," to study the operation of an air lock system at building pressures of 0.2 and 0.05 in. of water. These projects were developed by Laboratory personnel in cooperation with personnel from Camp Detrick, Maryland.

The modified protective shelter, complete with an air lock system, was pressurized and operated by Laboratory personnel. Tests were conducted at pressures of 0.2 and 0.05 in. of water above the outside static pressure for both the building shapes test and the air lock entrance test, and also at no pressure above the outside static pressure for the building shapes test. The aerosol attacks, using BW simulants, were made against the building and evaluated

by Camp Detrick personnel. Their data, discussion of results, and conclusions appear in Interim Report No. 104 (Confidential), "BW Evaluation of Port Hueneme Pressurized Building No. 7-635, January 1955," and Memorandum Report No. 9-65 (Confidential), "Evaluation of an Air Lock Entrance System."

It can be concluded from these tests that none of the three shapes tested would offer any added measure of protection to the interior of the building against the penetration of the BW aerosol agent; that a building when pressurized slightly above the outside static pressure would offer sufficient protection from the penetration of BW aerosols directed against it; and that in a shelter that is pressurized to 0.2 in. of water or less, the airflow through an air lock system of the types here tested is not sufficient to scavenge the air from each lock between the successive entrances of personnel.

Further development of an air lock system to determine the optimum design for maximum efficiency at the lower building pressures is recommended. Further consideration of special building shapes is not recommended at this time.

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INTRODUCTION

The Bureau of Yards and Docks assigned Project NY 300 006, "Personnel Shelters for BW," to the U. S. Naval Civil Engineering Research and Evaluation Laboratory for the development of equipment, materials, or procedures for use in existing buildings of the Naval shore establishment to provide emergency protection for personnel against BW aerosol attacks. This project is a continuation of Project NY 300 01B, "Operational Test of Protection for Buildings Under BW Attack," which was completed by the Laboratory in 1953. During September and October 1952, this Laboratory in cooperation with personnel from Camp Detrick, Maryland, conducted a series of three building pressurization tests^{1, 2, 3} on Building No. 7-635 at the U. S. Naval Construction Battalion Center, Port Hueneme, California. These tests were conducted to determine the efficiency of protection against a simulated BW attack of a wood frame building at various degrees of pressurization, and to test the operation of a conventional air lock system at a pressure of 0.6 in. of water and airflow of 400 cfm.

The results of these tests showed that this building, when pressurized to only 0.1 in. of water, still offered limited protection against infiltration of BW agents, and that at a pressure of 0.2 in. of water, the efficiency of protection was about the same as when pressurized to 0.6 in. The wind velocity during these tests was less than 10 mph. The air lock system operated satisfactorily at the 0.6-in. building pressure and an airflow of 400 cfm. No tests were conducted to determine effectiveness of the air locks at lower pressures and lower airflows.

Pictures of the smoke flow pattern over and around the pressurized building taken during the 1952 tests show that apparently there was a zone of relatively smoke-free air close to the wall on the upwind side. It was felt that this buffer zone, possibly caused by the eaves, might affect the amount of contamination reaching the wall.

The authorities at Camp Detrick were contacted regarding these observations and they concurred with the Laboratory in the need for further testing on Port Hueneme Building No. 7-635. The Physical Defense Division was directed to conduct the required BW tests at a mutually agreeable time. The details of the tests were worked out in a conference between Camp Detrick and NAVCERELAB personnel. It was agreed that there were two basic tests to be conducted. Purpose of the first series was to test the modified Building No. 7-635 to determine the effects of building shapes on the penetration of BW agents. The second series of tests were to be made on a conventional air lock system at low pressures and low airflows. It was further agreed in the conference that the tests would begin on 24 January 1955 and continue for an estimated three weeks.

As a result of these meetings and discussions, the Bureau of Yards and Docks initiated sub-task NY 300 006-5, "Effects of Building Shapes," to determine whether changing the airflow pattern around a building by altering its shape will affect the penetration of BW agents, and to study the operation of an air lock system when under a pressure of 0.2 and 0.05 in. of water.

EFFECTS OF BUILDING SHAPES

In order to utilize the basic building pressurization data which already had been collected,^{1,2,3} it was decided that Building No. 7-635, USN CBC, Port Hueneme, California, should be used for the tests. Dimensions of the building are: 161 ft long by 31 ft wide by 9 ft high under the eaves and 15 ft under the ridge. The total floor area is about 4800 sq ft, and its gross volume is approximately 52,000 cu ft. Net volume, less construction and the air lock system, is approximately 48,000 cu ft. The roof overhang measures 28 in.

Description

The building, erected on a concrete slab on grade construction, is rectangular, one-story, and has a pitched roof with the ridge centered longitudinally with the building. Figure 1 shows the general appearance of the building before modification. The framework is

of the usual 2 x 4 wood studding, and the external and internal walls are of 1/2-in. gypsum board, painted for weather protection. The outside joints, made over the studding, were made reasonably watertight by covering with wood batting strips. No effort was made to seal the base plate except that the gypsum board overlaps the foundation to form a weather barrier. The roof overhangs the wall and affords some weather protection. No special provision was made to seal between the roof and walls. The ceiling in the small rooms and in the corridor in the front half of the building is 9 ft high. The ceiling in the main portion of the building is covered with Celotex instead of the gypsum board and vaulted to a height of 14 ft at the center. The two small rooms in the rear of the building have no ceiling.

The outside doors are of the conventional wood-panel type, single or double, are metal weather stripped, and each contains a single pane of glass. The windows in the wash and utility rooms are small, hinged at the bottom, and swing in. The majority of the windows are of the large Japanese sliding type, running in loosely fitting wooden grooves.

The roof is fabricated from 1-in. gypsum board nailed to 2 x 6 rafters and covered with an asphaltic roofing paper cemented at the joints. The roof space is vented at the front of the building through a louver, which was sealed for the test.

The building was completely sealed for the 1952 BW tests with strippable plastic coating compound, Federal Supply Stock No. GF8030-275 (formerly, Navy Stock No. G52-C-2250). Between the 1952 tests and the tests being reported on here, the building was used for many other purposes, so that most of the seals on the doors and windows had been removed. Therefore, the building was again made reasonably airtight by sealing with the strippable plastic. Preliminary tests showed that the building could be successfully pressurized to the degree required.

Modifications

The outside of the building was divided approximately into thirds for the Effect of Building Shapes tests. Figure 2 shows the building after the modifications were completed. Figure 3 shows the floor plan for the test building. The first third of the building was designated

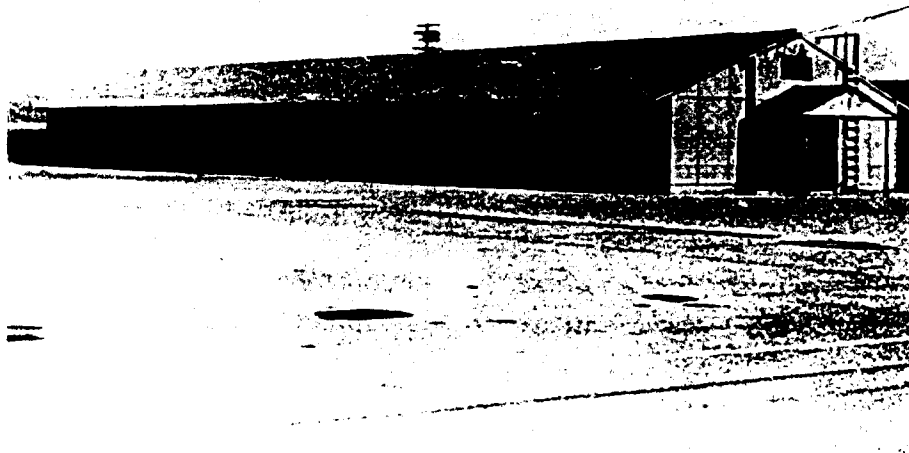


Figure 1. Port Hueneme Pressurized Building before modifications.

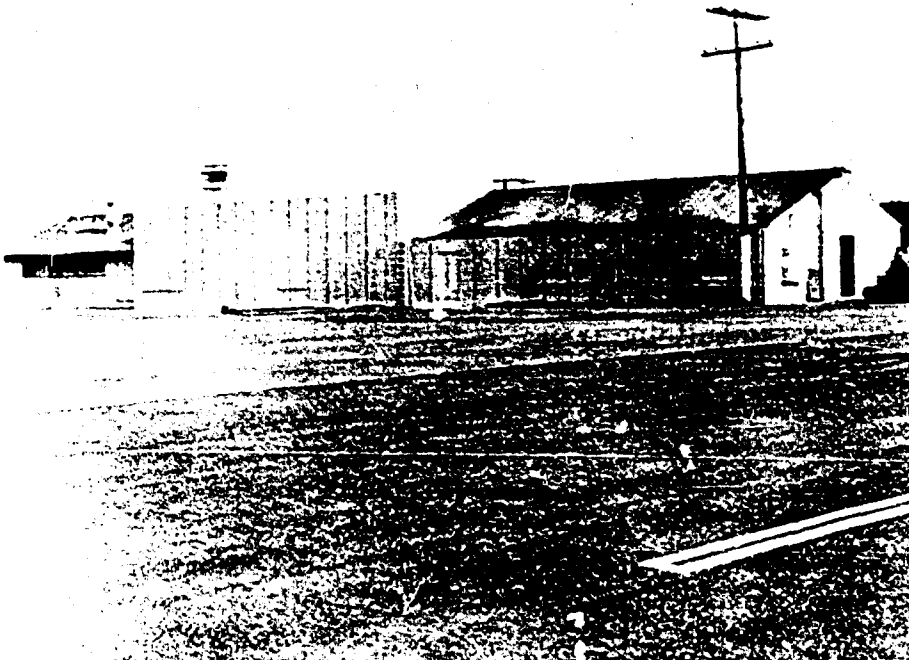


Figure 2. Port Hueneme Pressurized Building after modifications.

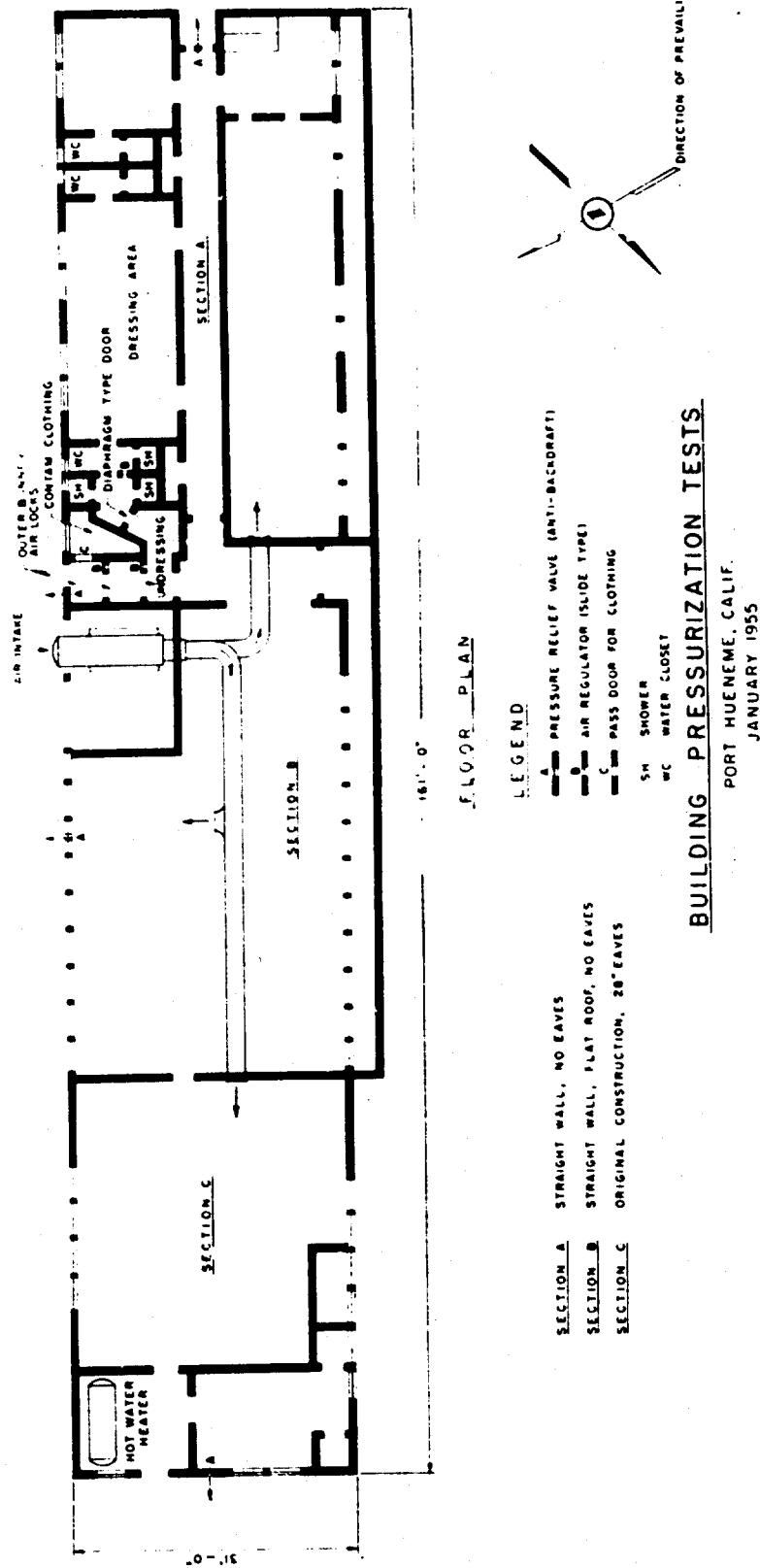


Figure 3. Floor plan of Building No. 7-635.

as Section A and was selected to represent the original building but without the 28-in. eaves. This was done by constructing a false wall from the tip of the eaves to the ground, in effect, the same as removing the eaves. The second section of the building was selected to represent a straight-walled building with a flat roof. This required that a false wall, extending from the edge of the eaves, be erected from the ground to a point even with the peak of the roof. The third section remained the same as when the building was tested during the 1952 BW tests.

All of the new outside construction was of a temporary nature. The outside walls of Sections A and B were constructed of 1/2-in. gypsum board nailed to 2 x 4 wood studding placed 24 in. on centers. All of the vertical joints were covered with wood stripping to make them reasonably weathertight. The horizontal joints were sealed with a plastic compound. The walls were painted with one coat of Navy gray for protection against the weather.

The temporary false roof was constructed over the original roof construction and was built from 1/2-in. plywood nailed to 2 x 4 wood trusses placed 24 in. on centers. The plywood was mopped with hot asphalt and then covered with three layers of felt paper to make it waterproof.

The inside of the building was divided into three sections to correspond to the dividing line of the three outside wall sections. Each section of the building was completely sealed off from the others. To divide Sections B and C, a temporary wall was constructed of 1/2-in. gypsum board nailed to 2 x 4 wood studs. A door was installed in this wall for easy access between the sections when no tests were in progress, but was metal weather stripped to effect a seal when it was closed. The joint between the temporary wall and the original wall construction was sealed with strippable plastic coating compound. Sections A and B were separated by making use of the existing walls. The doors in these walls were either sealed with masking tape and sprayed with the strippable plastic or were metal weather stripped.

Four anti-backdraft valves, Model E1R5, were procured from the Army Chemical Corps for use on the test building to regulate pressure and airflow. One of the valves was inserted in the outside wall of each of the test sections, and the remaining valve was installed in the outside wall of the outer air lock.

The air lock system, the modifications of which are explained in the next section, was not in operation during the tests described under Effects of Building Shapes.

The Army Chemical Corps E-35 collective protector, rated at 5000 cfm of air, was used to provide filtered air to the test building. Figure 4 shows the E-35 connected to the test building, ready for use. Duct work carried the air to the three sections from the filter unit. Figure 5 shows the airflow measuring section and the distribution ducts from the E-35 collective protector. The unit used during these tests was the same one used in the 1952 BW tests. However, a new particulate filter was obtained from the Army Chemical Center, Maryland, and was installed on the unit before any testing took place. Some difficulty was encountered in changing the particulate filter on the E-35 collective protector. In the space available, it was extremely difficult to remove the plywood boards covering the joint between the particulate and the gas filter. The particulate filter itself was bowed on all four sides when received from the ACC, which made fitting it with the charcoal unit difficult, and necessitated the use of much asphaltic compound to fill in the voids.

A fan was installed over the door in the front room of Section A and in the interior wall of the back room of Section C to increase the circulation of air in those sections where a dead air space could possibly form.

The windows of Sections A and B on the north wall facing the new construction were left open during all tests to increase circulation of air in the space between the old and new wall.

Instrumentation

The instrumentation reported here includes only that used for recording data concerning the mechanical operation of the building. Since this operation was a joint Camp Detrick-NAVCERELAB venture, Camp Detrick's report will cover the description of the instrumentation needed for detecting, recording, and evaluating the numerous samples taken during the tests.

The method used during the tests to measure the building pressure so as to obtain true readings and to avoid fluctuations in the manometers was suggested by Camp Detrick's contractor, the

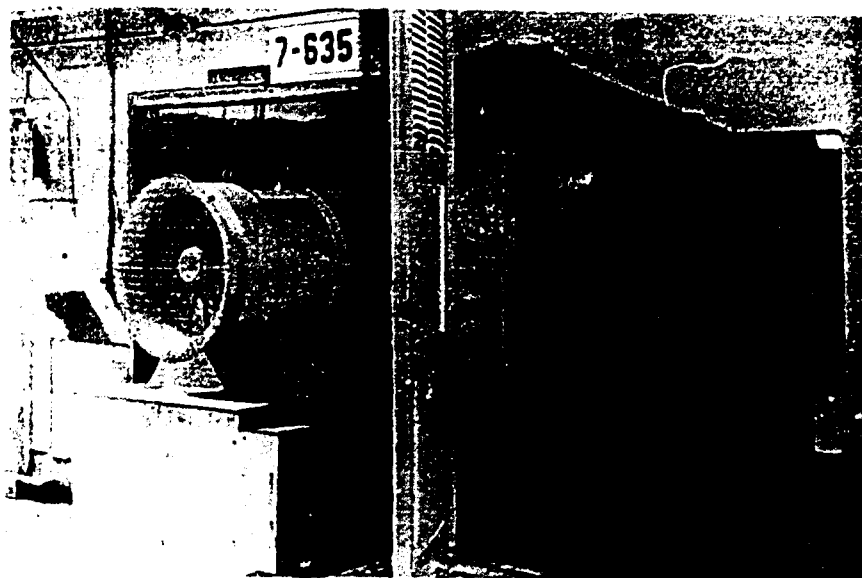


Figure 4. Chemical Corps E-35 collective protector installed.

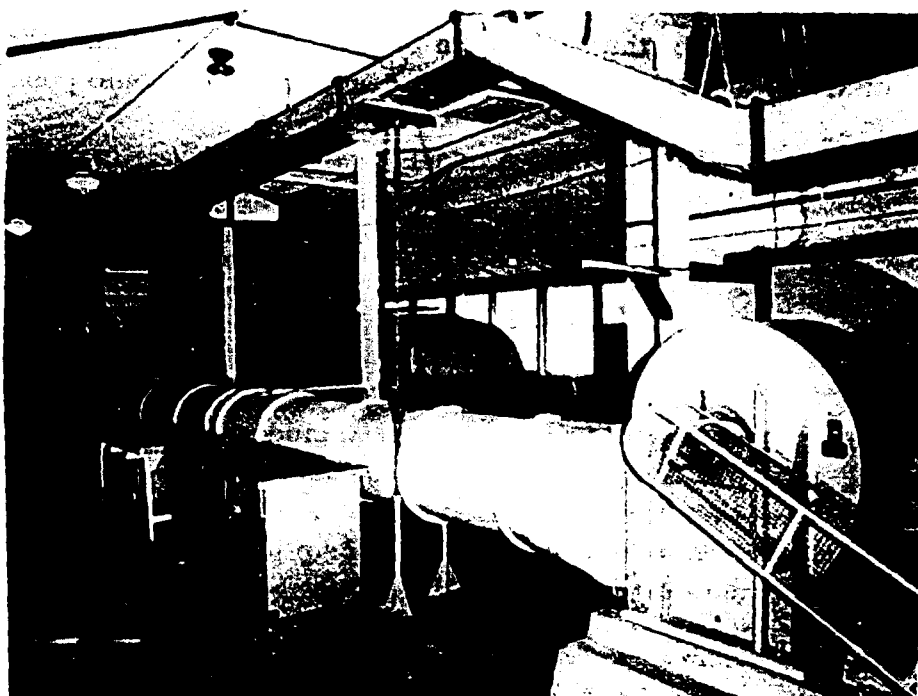


Figure 5. Air-measuring and air-distributing ducts from E-35 collective protector.

Texas Engineering Experiment Station, College Station, Texas.⁴ This pressure was measured by running copper tubing from each section of the building and from an outside tap to a manifold connected to an inclined manometer. By proper manipulation of the valves at the manifold, the static pressure of the various sections above the outside static pressure can be measured. The inside taps consist of the open end of the copper tubing placed in the section to be measured. The tap measuring the outside static pressure was located at a point 75 ft from the northwest side of the building in an open field at a height of about 6 ft, and consisted of the static part of a standard Pitot tube which was attached to a wind vane in such a manner that the tube would always face into the wind.

The total airflow from the E-35 collective protector into the building was accurately measured in a calibrated section of the air distribution duct using a Taylor Pitot-Venturi tube as the sensing element. To obtain information on the distribution of the air to the three sections of the building, a Taylor Model 3132 vane-type anemometer was used to measure the air velocity at each outlet and thus calculate the airflow. The figures obtained by this last method of flow measurement are used only to determine the percentage or distribution of total air entering each section.

Meteorological data taken during the tests included wind speed and direction, outside air temperature, and outside humidity. The wind speed and direction were continuously recorded on Bendix-Friez standard weather bureau type equipment. The maximum, minimum, and average wind speed, and average wind direction were recorded on the data sheets at intervals of 10 min during all tests. The temperature and humidity of the outside air was continuously recorded on a Bendix-Friez hygrothermograph which was calibrated daily. This information also was recorded on the meteorological data sheet at appropriate intervals during all tests.

Tests

In accordance with the agreements made at the various pre-test conferences, Camp Detrick personnel were in over-all charge of the BW phase of the operation, while NAVCERELAB personnel were in charge of the mechanical (or operational) phase of testing. Camp Detrick furnished the laboratory and field personnel, the BW agents,

the aerosol-generating and the other field and sampling equipment. NAVCERELAB furnished personnel for the mechanical operation of the test building and the recording of the necessary pressure, airflow, and meteorological data, the test building complete with all necessary equipment and instrumentation, and laboratory space complete with necessary equipment and additional personnel for processing the many bacterial samples. The complete report on the methods of aerosol generation, the sampling and laboratory procedures, and the evaluation and discussion of the results of the numerous samples are contained in Interim Report No. 104 (Confidential), and Memorandum Report No. 9-65 (Confidential), issued by Camp Detrick.^{5, 6}

Filtered air was distributed to the three test sections through sheet metal ducts from the Army Chemical Corps E-35 collective protector. During the three Effects of Building Shapes tests, no attempt was made to maintain a particular or designated airflow. The primary concern during these tests was the maintenance of the designated building pressure. Once the testing had begun, the building was continuously pressurized to prevent infiltration of any stray contaminants between tests.

During the three building shapes tests, the three sections under test were completely separated by closing the doors and sealing all other openings. There was no air movement between sections. The circulating fan in the front room of Section A and the back room of Section C was operated during all the tests. The building pressure was maintained, as required, in each section by adjusting the anti-backdraft valves located in each section and controlling total flow of air from the collective protector. Figure 6 shows a general view of the test area and the Camp Detrick equipment in use during one of the building shapes tests.

TEST NO. 1

The pressure in the testing building was maintained at or very close to the 0.2 in. of water as specified in the test plan. An aerosol of Bacillus globigii was produced upwind from the test building and maintained for three hours. Aerosol samples were taken inside and outside the building as required during this period by Camp Detrick personnel. A tabulation of meteorological conditions prevailing during this test is given in Table I. Total airflow into the building varied from 2350 cfm to 2625 cfm, with approximately one-third of this total entering each section.



Figure 6. General view of test area.

TABLE I. Meteorological conditions prevailing during Effects of Building Shapes tests.

Test no.	Wind				Outside air temp (deg F)	Outside humidity (%)
	Speed (knots)			Direction		
	Avg	Max	Min	Avg		
1	6+	8.5	6	ENE to W	50-55	72-84
2	6	6	6	W	55-57	60-85
3	8	16	6	N to NW	51-61	42-100

TEST NO. 2

The pressure in the test building was maintained at or very close to the 0.05 in. of water as specified in the test plan by lowering the output of filtered air from the collective protector. An attempt was made to supply the building with an absolute minimum of filtered air, yet still have a very slight positive pressure. The relief dampers were inoperative during these tests. The BW aerosol was generated in the same manner as that in Test No. 1. The meteorological conditions prevailing during this test are shown in Table I. The total airflow into the building was approximately 750 cfm, with about one-third of this total entering each section.

TEST NO. 3

The test building was operated at or near the ambient atmospheric pressure with no air entering the building through the collective protector. The BW aerosol was generated in the same manner as Test No. 1, except that the period of aerosol generation was six hours. Sampling inside the building continued for an additional two hours. Table I shows the meteorological conditions prevailing during the test.

AIR LOCK ENTRANCES

In order to determine the effectiveness of conventional air lock systems at building pressures of 0.2 in. of water and less, it was decided that the existing air lock system in the Port Hueneme pressurized building, previously described, would serve the purpose. Diaphragm-type doors in place of the conventional doors were also to be investigated. As a result of the 1952 building pressurization tests, it was recommended that the building pressures be lowered to 0.2 in. of water; however, no tests were conducted at that time to determine whether the air locks would offer the desired protection.

Description

The air lock system shown on the floor plan of the building, (see Figure 3), was built to fit existing facilities and does not represent the optimum in design. The air lock system consists of the outer and inner air locks, the undressing area, shower, and dressing area, and a room in which to throw the contaminated clothing. Standard Chemical Corps slide-type valves were installed between these compartments for regulating air pressure and airflow. A Chemical Corps anti-backdraft valve was installed in the outer air lock to relieve the air lock pressure to the outside and to prevent the infiltration of contaminated air through that opening. Air normally travels from the higher pressure area (main shelter area) by the regulating valves through the various compartments to the outside. The pressures in each compartment are successively reduced to allow a maximum of airflow. Because of the low building pressures involved in these tests, no attempt was made to specify any given pressure for the compartments or to maintain a given airflow through the air locks. However, the slide-type valves were regulated to give a differential pressure in

each compartment, down to nearly atmospheric pressure in the outer compartment. A diaphragm-type door, Figure 7, as developed by the Chemical Corps Chemical and Radiological Laboratories, in cooperation with their contractor, the University of Florida,⁷ was installed in the passageway between the undressing area and the showers.



Figure 7. Diaphragm-type air lock door.

Two more diaphragm doors were constructed for certain air lock tests to be described later, and provision made to install them in place of the solid flush-type doors between the outer and inner air lock, and the inner lock and the undressing area. These diaphragm-type doors

are constructed of elastic, one-way stretch girdle fabric, as manufactured by the United Elastic Corporation, Littleton, Massachusetts.

An auxiliary blower was installed between the undressing area and the main shelter area for pressurizing the air locks and increasing airflow during the test when the two additional diaphragm-type doors were in use. Figure 8 shows this blower installed and ready for use.

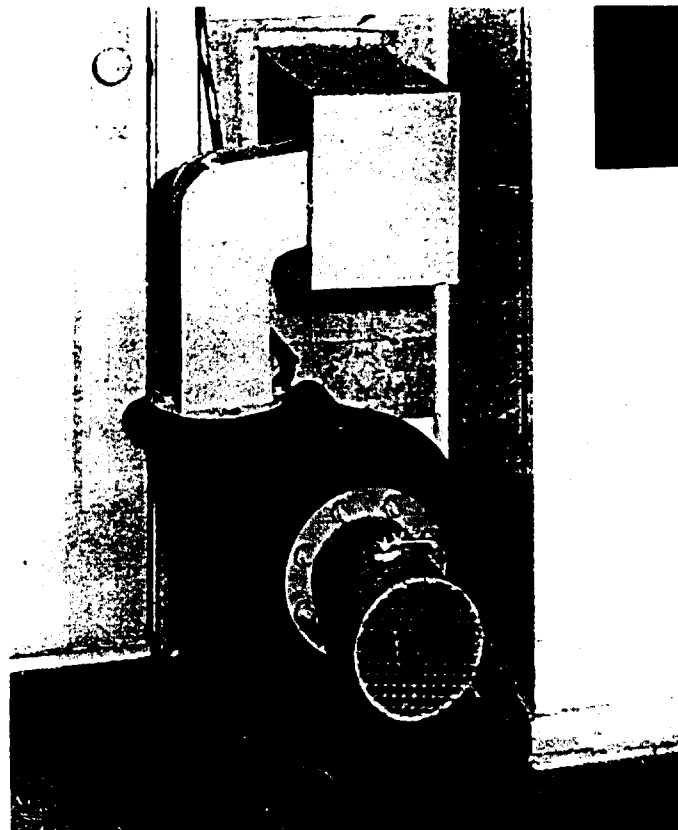


Figure 8. Auxiliary air lock blower.

An attempt was made to determine if this auxiliary blower would successfully pressurize the air lock and provide the necessary airflow without having to overpressurize the main shelter area.

Instrumentation

The airflow, building pressure, and meteorological data were recorded during these tests from the same instruments as reported in the Effects of Building Shapes test. Pressure taps were installed,

as in the building shapes test, in the various compartments of the air locks for determining the pressure differentials. Airflow passing through the air locks, and also that supplied by the auxiliary blower when it was tested, was determined by using a Taylor Model 3132 vane-type anemometer for measuring air velocity and then calculating total airflow.

Tests

As in the Effects of Building Shapes tests, Camp Detrick personnel were in charge of the BW phase of the operation, while NAVCERELAB personnel were in charge of the operational phase. Equipment and personnel furnished by the two installations were largely the same, except that USN CBC supplied the subjects for the entrance tests and NAVCERELAB supplied the many changes of clothing required. As in the previous tests, the complete report on the BW phase is contained in Memorandum Report No. 9-65 (Confidential), issued by Camp Detrick.⁶

Filtered air was distributed to the building through sheet metal ducts from the Chemical Corps E-35 collective protector. During the three air lock entrance tests, no attempt was made to maintain a specified airflow through the air lock system, except that the airflow was to be as high as could be obtained with the physical setup at hand. Also, no specified pressure differentials were to be maintained, except that the pressure was to be successively lowered from the designated building pressure to a pressure near atmospheric pressure in the outer air lock. Maximum airflow was obtained by properly adjusting the anti-backdraft valve located in the outer air lock and by manipulating the slide-type regulating valves between the other air lock compartments.

The subjects were heavily contaminated with the BW aerosol simulant, which was generated inside a building a short distance away from the test area before being used in the entrance tests. A portable canvas tent 16 ft long by 8 ft wide by 10 ft high, of the type used to house equipment in adverse weather, was installed at the entrance to the air locks. This tent was used to house the BW aerosol generators so that the subjects entering the building for the tests would receive additional contamination before entry, and also to insure a high concentration of aerosol around the outside entrance to the air lock without requiring contamination of the entire building.

TEST NO. 4

The pressure in the main shelter area of the test building was maintained at 0.2 in. of water in accordance with the test procedure. This test was conducted with 25 heavily contaminated subjects entering the shelter through the permanent or conventional-type air lock system at two-minute intervals. As previously stated, a diaphragm-type door was located in the passageway between the undressing area and the showers. A tabulation of the average air lock and building pressures actually maintained and the meteorological conditions prevailing during this test are given in Table II. Average airflow into the building during the test was determined to be 1788 cfm, while the airflow through the air locks was 113 cfm, as measured with a vane-type anemometer. The high wind velocity experienced during the test was not expected to affect the results, since the air locks were on the lee side of the building and the entrance was enclosed in a tent.

TABLE II. Meteorological conditions prevailing during portable air lock tests.

Test no.	Wind				Outside air temp (deg F)	Outside humidity (%)	Pressure (in. H ₂ O)			
	Speed (knots)			Direction			Building	Undress area	Inner air lock	Outer air lock
	Avg	Max	Min							
4	25	48	12	NE to E	61-66	12-18	0.21	0.17	0.13	0.10
5	23	40	13	E	67-68	10-11	0.049	0.043	0.038	0.035
6	18	33	8	NE to E	67-68	10	0.034	0.071	0.049	0.036

TEST NO. 5

The pressure in the main shelter area of the test building was maintained at or very close to 0.05 in. of water above the outside static pressure, in accordance with the test plans, by practically shutting off the air intake to the oversize E-35 collective protector. This test was conducted with 25 contaminated subjects entering the shelter area through the conventional-type air locks at two-minute intervals. As in Test No. 4, a diaphragm-type door was located between the undressing area and the showers. The air lock and building pressures that were actually maintained and the meteorological conditions prevailing during this test are shown in Table II. It was estimated that the airflow into the building was 400 cfm, while the airflow through the air locks was determined to be approximately 37 cfm. As in Test No. 4, the high wind velocity was of no major concern because of the nature of the tests.

TEST NO. 6

The pressure in the main shelter area of the test building was maintained at 0.05 in. of water, as in Test No. 5. During this test, the flush-type doors between the outer and inner air locks and the inner lock and dressing room were replaced with the diaphragm-type doors. This was in addition to the diaphragm-type door located between the undressing area and the showers. The auxiliary blower, which was installed between the undressing area and the main shelter area for pressurizing the air locks and increasing airflow, was placed in operation for this test. This blower had been previously sealed off to prevent leakage during the other tests. The slide-type air regulator valves were closed and sealed so that all air would be forced through the porous material of the diaphragm-type doors, so that the sweeping action would be uniform. This test was conducted with 25 contaminated subjects entering the shelter area through this experimental-type air lock system at two-minute intervals. Table II shows the pressures actually maintained and the meteorological conditions prevailing during the test. Airflow into the building was not measured. The airflow through the air lock, as measured at the anti-backdraft valve, was approximately 41 cfm. The auxiliary blower supplied 658 cfm to the undressing area. Unfortunately, however, the resistance of the flow of air through the air lock system was higher than that back into the building, so that most of the air supplied by this blower was recirculated back into the main shelter area. As in the two previous air lock entrance tests, the high wind velocity encountered was of no major concern.

RESULTS AND CONCLUSIONS

Because of the nature of the tests reported here, all of the results are obtained from the evaluation of the many bacteriological samples collected by Camp Detrick personnel. A tabulation of the bacterial data collected and a complete discussion of the results and conclusions obtained from those samples are included in Interim Report No. 104 (Confidential), and Memorandum Report No. 9-65 (Confidential), issued by Camp Detrick.^{5, 6}

The following information is based on the conclusions as reported by Camp Detrick in their report on the tests:

1. It can be concluded from the results of the Effects of Building Shapes tests, that there was no significant difference in the amount of contaminants reaching the walls of the three shapes

tested and that none of the shapes would offer any added measure of protection against the penetration of the BW agents unless the walls were sealed and the building was pressurized.

2. It can also be concluded from the tests on building shapes that a building, when pressurized only slightly above the outside static pressure, will offer sufficient protection from the penetration of BW aerosols directed against the building.

3. The data obtained during the air lock entrance tests show that none of the three systems tested was effective in keeping the BW aerosol from entering the building through the air lock system during the entrance of personnel. It may be concluded, then, that when a building is pressurized to 0.2 in. of water or less, the airflow through air lock systems of the types here tested is not sufficient to scavenge the air from each lock between the successive entrances of personnel.

RECOMMENDATIONS

1. It is recommended that no further consideration be given at this time to special building shapes as a means of protecting buildings against the penetration of BW aerosol agents.

2. It is also recommended that further testing be conducted on air lock systems to determine the optimum design for maximum efficiency at the lower building pressures. This work should be done on a portable or movable air lock system so that interior dimensions and internal equipment can be modified or changed as required.

REFERENCES

1. Chemical Corps Biological Laboratories, Physical Defense Division, Special Report No. 171 (Confidential), BW Evaluation of Pressurized Building No. 7-635 at Naval Civil Engineering Laboratory (1952), by Frederick T. Lense, 10 May 1954.
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